Ethernet 101 for Automotive

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Agenda

• Networking Technology & Standards
  – Ethernet the way it really is!

• Ethernet In-Vehicle Networking
  – Using Ethernet in a constrained/controlled environment
  – Ethernet PHY example roadmap
What am I trying to show?

- Ethernet already has the fundamental toolkit in place
  - and there is a huge market and technology momentum
  - highest performance, lowest cost, widest adoption (proven)

- Adapting Ethernet to vehicular requirements is straight-forward
  - and has significant fundamental advantages over the alternatives
  - AVB (now) and AVB gen 2 (future) provide the next set of tools
  - physical layers optimized for automotive and control applications
Ethernet 101:
The way it really is

• All links run at 100 Mb/s or faster
  – 1 Gb/s links are now outselling 100 Mb/s
  – 100 Mb/s is “free” (included in most consumer-electronics-based SoC’s)

• Ethernet is a switched network
  – there are no shared media (e.g. hubs, repeaters)
  – “CSMA/CD” is dead, there is no “media access protocol”

• Ethernet switches are really smart
  – priorities, virtual LANs, QoS by deep packet inspection
  – “spanning tree” and “shortest path bridging” eliminates loops
  – “link aggregation” takes advantage of redundant paths
Ethernet 101:

The way it really is (cont.)

• Ethernet PHYs are really smart
  – automatic pair alignment
  – cable diagnostics (impairment measurement and location)

• Ethernet runs on all kinds of media
  – UTP (1-pair for BroadR-Reach, 2-pair for 100Mb/s, 4-pair for 1Gb/s and 10Gb/s)
  – STP (10G short range)
  – optical fiber (multimode or single mode, silica or plastic)

• Ethernet does not have to run at “decade” rates
  – 2.5G widely deployed in data centers
  – “SONET” infrastructure used for Ethernet links as well
Ethernet 101:

Security

• Switched network, remember?
  – All connections are point-to-point, not shared

• “MACSEC” is a hop-by-hop, link-specific security system
  – Devices on each end of a wire link can encrypt data just for a known device on the other end
  – Extended to support login (same technique used in “WPA” for WiFi)
  – Extended further to support robust device ID
Ethernet 101:
The way it is coming to be

- 10 Gb/s deployment is ramping up
  - currently data center and telecom / short range copper / long range fiber
  - UTP (four pair Cat 6a ramping for data center / video)

- 40 and 100 Gb/s standardization complete
  - for optical fiber ribbon
  - new project for shielded twisted pair (STP)

- “Energy Efficient Ethernet” standardization is complete
  - automatic and very fast power scaling with traffic requirements
  - deployed NOW

- “FireWire”-type streaming QoS services coming soon
  - IEEE 802.1 Audio Video Bridging

- Congestion management for data
  - “no dropped packets” IEEE 802.1au, 802.1bb
Ethernet 101:

Synergies

- Almost all networked devices have an Ethernet port
  - least common denominator
- Baseline assumption for IP networking
  - must work on Ethernet
- Baseline network for DLNA
  - along with WiFi
- Market volumes are *huge*
  - Broadcom alone shipped over a billion ports by 2004
  - Technology and production investment continues
How do we use it?

- Enormous flexibility in deployment
- Ethernet switching standard allows for
  - many cable hops
  - star, daisy-chain, ring ... any topology
- Rings or meshes OK for redundancy
  - “spanning tree” will disable redundant links
  - or redundant links can be used together in “link aggregation”
- Devices can have built-in switch to encourage daisy-chaining
  - currently done with VOIP phones
Topology with redundancy

redundant paths:
both could be active for productive redundancy
Topology without redundancy
IEEE 802.1 Audio Video Bridging

- The IEEE 802.1 AVB Task Group was responsible for developing standards that enable time-sensitive applications over IEEE 802 networks
  - the IEEE 802.1 Working Group is responsible for bridging (including Ethernet “switches”)
  - interoperability between networks of differing layer 2 technologies

- The primary projects completed:
  - queuing and forwarding of time-sensitive streams (“credit-based shaper”) – part of IEEE Std 802.1Q-2012 “VLAN networks”
  - registration and reservation of time-sensitive streams (“stream reservation protocol”) – part of IEEE Std 802.1Q-2012 “VLAN networks”
  - time synchronization (“generalized Precision Time Protocol – gPTP”) – IEEE Std 802.1AS-2011
  - overall system architecture (IEEE Std 802.1BA-2011 “Audio Video Bridging Systems”)
Unified Layer 2 QoS

- Enhance network bridging
  - Define common QoS services and mapping between different layer 2 technologies
  - IEEE 802.1 is the common technology

- Common endpoint interface for QoS
  - “API” for QoS-related services for ALL layer 2 technologies
  - Toolkit for higher layers
  - Provide network independence for endpoints without giving up QoS
AVB services only in the “AV cloud”

devices outside of AV cloud still communicate with all other devices using legacy "best effort" QoS
Audio Video Bridging Services

- 2 ms bounded latency through 7 Ethernet bridges
  - linear relationship with the number of bridges
  - delays through cooperating 802.11 systems TBD, but much longer

- SRP reserves link resources
  - For Ethernet, bandwidth is the primary resource
  - For coordinated shared media (802.11, G.hn, MoCA) resource management is more complex

- Precise timing and synchronization services for timestamps and media coordination
  - <1µs instantaneous synchronization between devices
  - delivered clock provides a reference that can meet the jitter and wander requirements (MTIE mask) for HD-SDI and AES audio streams
New services / technology / standards

• Ethernet is in continuous development
• New physical layers
  – 40GbaseT, reduced-pair PHYs
• New reliability enhancements
  – Multiple paths / simultaneous paths for critical traffic
• New delay reduction technologies
  – Scheduled queues, preemption, burst limiting queues
• These could all be parts of “AAA2C”
  – But they are going to be standardized / deployed in any case
An example “new technology”

• Ethernet designed for much longer distances
  – UTP for 100m
  – 3 connector interfaces in series (jumper-backbone-jumper)

• Perhaps we can use this for extra margin to gain resistance to interference?
  – example: Broadcom’s “BroadR-Reach” PHYs use 1G technology to go 500m at 100 Mb/s using 4 pair or even 500m over a single pair at 10Mb/s
    • Lower cost replacement for DSL
  – Use the same idea to provide Ethernet unshielded single pair PHY operating at 100 Mb/s
    • Uses same concept as 4x UTP 1GbaseT
    • Uses existing auto cable/connector technology
Layer 2 Technology Roadmap

- Possible new generation reduced pair UTP (wired connections for automotive and control)
  - 250baseOneT (using lessons from 100) - a few years
  - 1GbaseOneT (using lessons from 250 and standard 10GbaseT) - a few more years
  - 2.5GBaseOneT (or 2.5GBaseTwoT) - maybe 6-8 years
  - (Maybe two pair ... not decided yet)

- Wireless
  - 2.4GHz/5GHz 802.11 can be AVB compliant (802.11v and 802.11aa updates) – up to 1Gb/s, with variable QoS
  - 60GHz "WiGig" can be AVB compliant (802.11ad), good for short range ... inside passenger compartment
# Automotive AV network comparison

<table>
<thead>
<tr>
<th></th>
<th>Ethernet AVB + BroadR-Reach</th>
<th>MOST</th>
<th>IDB-1394 “FireWire”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Architecture</strong></td>
<td>switched</td>
<td>shared synchronous ring</td>
<td>shared bus</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td>star, daisy-chain, ring –all with optional productive redundancy</td>
<td>ring</td>
<td>star, daisy-chain, ring - all with optional redundancy</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>100 Mb/s, 1000 Mb/s, 10 Gb/s widely deployed – 40/100 Gb/s in development – many other rates used in private networks … per link</td>
<td>25 Mb/s common, 150 Mb/s in early deployment … shared</td>
<td>100, 200, 400, 800 Mb/s widely deployed – 1.6Gb/s in prototype, 3.2Gb/s specified … shared</td>
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<tr>
<td><strong>Medium</strong></td>
<td>single UTP (Flexray or equivalent at 100 Mb/s), multiple UTP/STP, coax, all types of fiber</td>
<td>Plastic Fiber, UTP</td>
<td>fiber and STP up to 800Mb/s, UTP to 100Mb/s – UTP up to 800Mb/s specified</td>
</tr>
<tr>
<td><strong>Sample rate / time synch support</strong></td>
<td>Any arbitrary native rates ~ 100 ps jitter - &lt;1 us synchronization</td>
<td>44.1 KHz native, sample rate conversion for other rates</td>
<td>Any arbitrary native rates ~ 100 ps jitter - &lt;1 us synchronization</td>
</tr>
<tr>
<td><strong>Diagnostics</strong></td>
<td>Built-in Cable Diagnostics that checks open, short, location of fault, quality of the medium.</td>
<td>??</td>
<td>??</td>
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<tr>
<td><strong>Cost</strong></td>
<td>Low-cost, approaching analog system, many billions of ports deployed</td>
<td>Higher, less than a million ports deployed</td>
<td>Higher, no deployment, but over one billion 1394 ports</td>
</tr>
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Conclusion

- Ethernet offers true networking at competitive costs
- Data rates are compatible with automotive and control use cases now
  - With a robust technology road map
- Quality of Service is compatible with camera/audio/video use cases
  - Bounded latency, guaranteed bandwidth, precise synchronization
  - Improvements in the pipeline for control applications
- Modest reuse of existing technology for auto use
  - Existing auto-qual single unshielded twisted pair and connectors
Thank you!